Potential Emission Reductions from Advanced Power Generation

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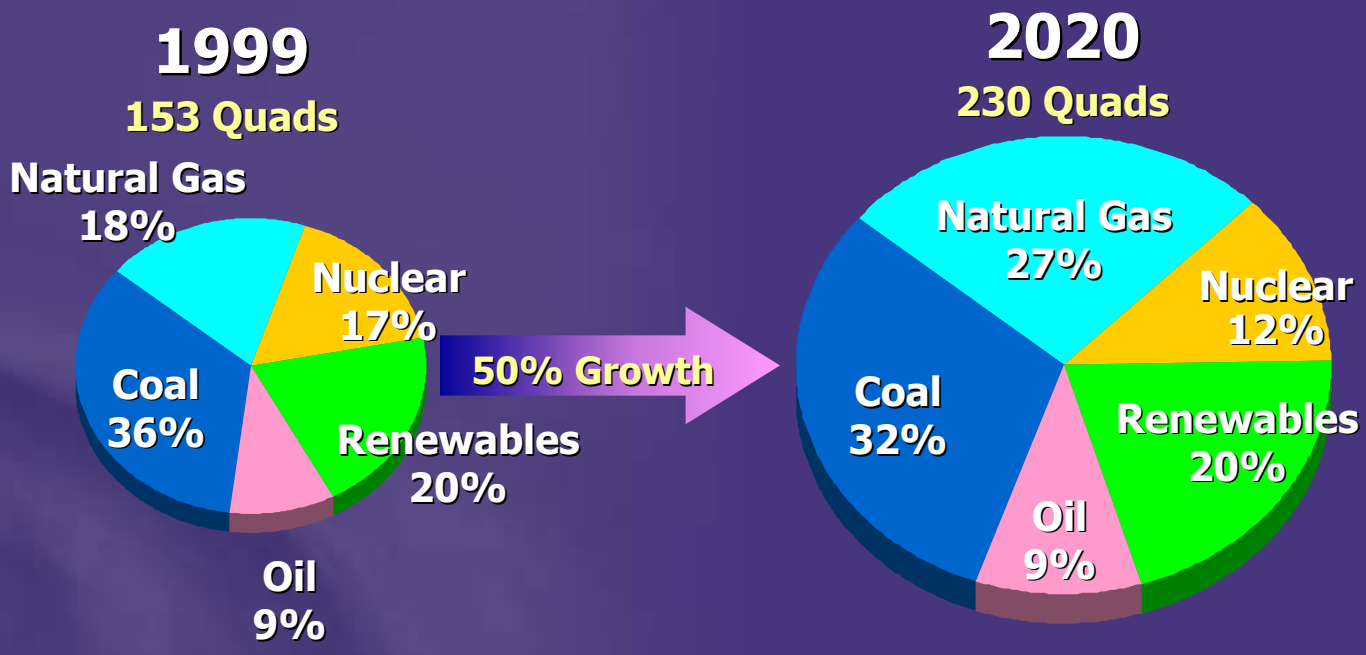
Overview

- Background
- Emission Reduction Technologies for Existing Fleet
- Emission Reduction Technologies for New Fleet
- Conclusions

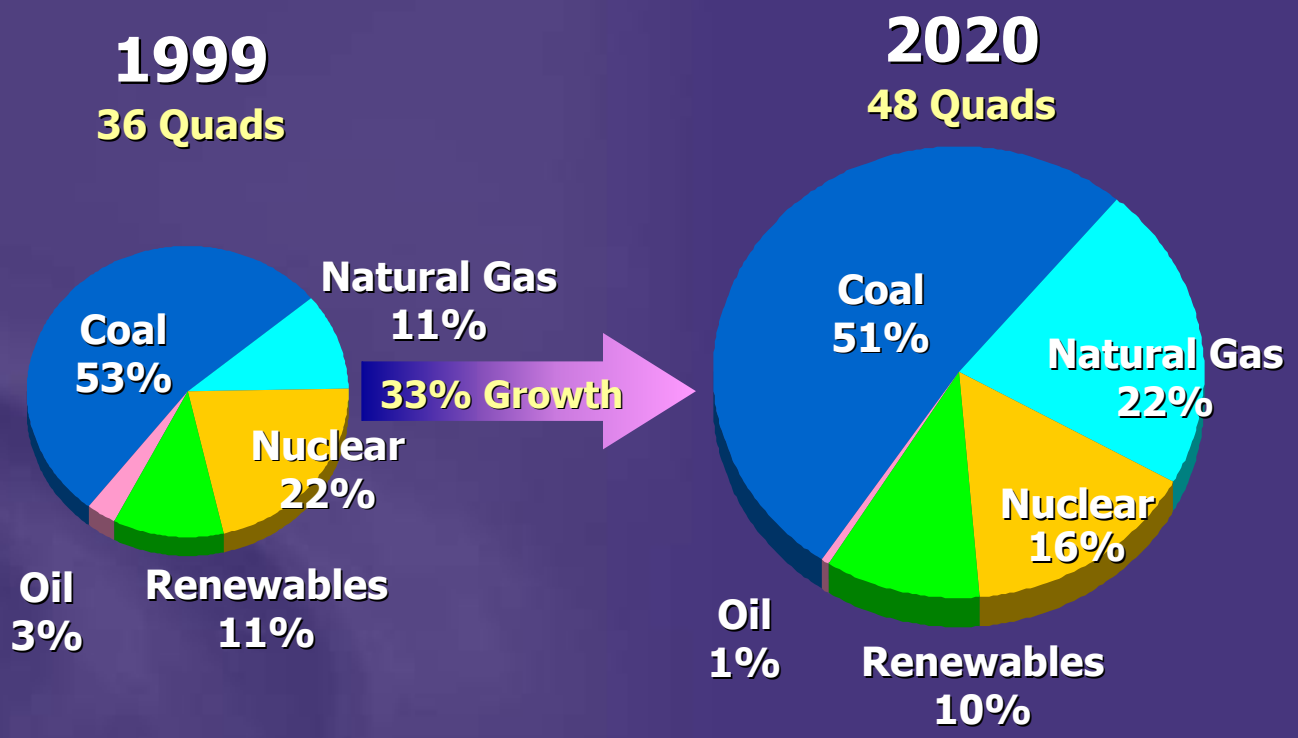
World Electricity Consumption



Source: IEO2002, Table 21

Worldwide electricity consumption is projected to grow at an average rate of 2.7% between now and 2020

U.S. Electricity Consumption



Source: AEO2002, Table A2

By 2020, 355 gigawatts of new generating capacity are expected in the U.S. alone to meet growing demand and to replace retiring units

Fuels for Electricity Generation

- Continued increase in the use of natural gas for electricity generation is expected worldwide
- Coal is expected to retain the largest market share, but its dominance will be reduced by the rise in natural gas
- The role of nuclear power is projected to lessen as reactors reach the end of their lifespans and few replacements are built
- Electricity generation from hydropower and other renewables is expected to grow by more than 50% over the next 20 years, but their share of total production is expected to remain near the current level of 20%

Emission Reduction Targets

- President's Clear Skies Initiative
  - Dramatically and steadily cuts power plant emissions of three worst air pollutants (3-P Proposal):
    - Caps sulfur dioxide (SO_2) emissions at 3 million tons by 2018, or a 73% reduction
    - Caps emissions of nitrogen oxides (NO_X) at 1.7 million tons by 2018, or a 67% reduction
    - Cuts mercury (Hg) emissions by 69% – the first ever national cap on mercury emissions, capped at 15 tons in 2018
  - Reduces greenhouse gas intensity by 18 percent over the next 10 years

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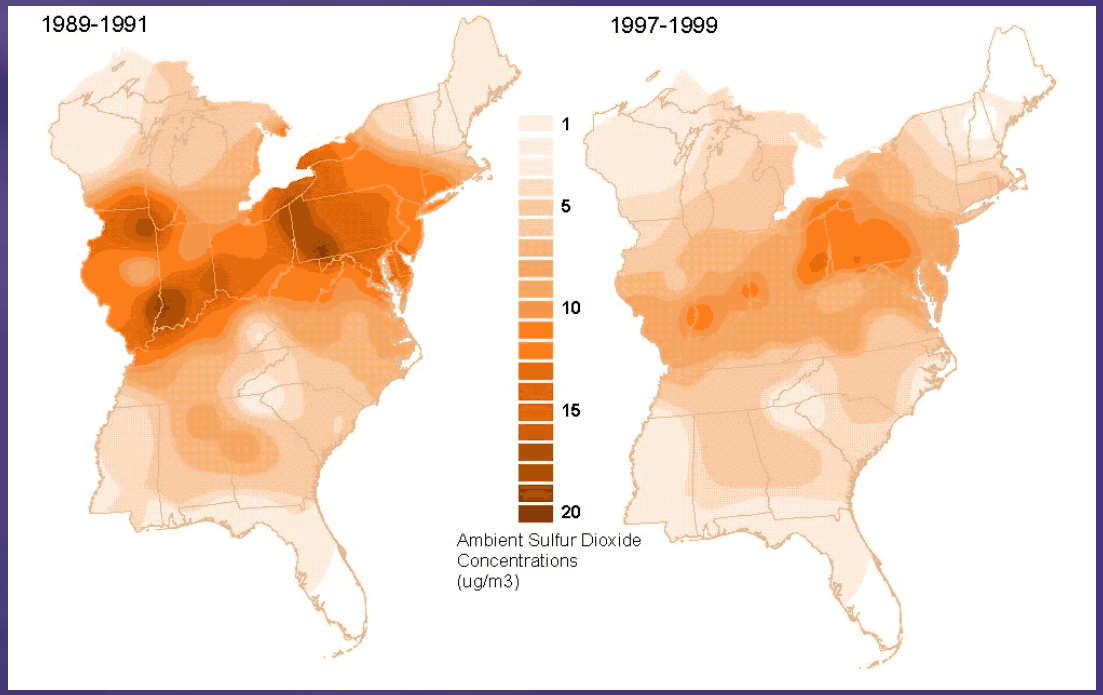
Benefits Legacy from CCT Program and Associated R&D

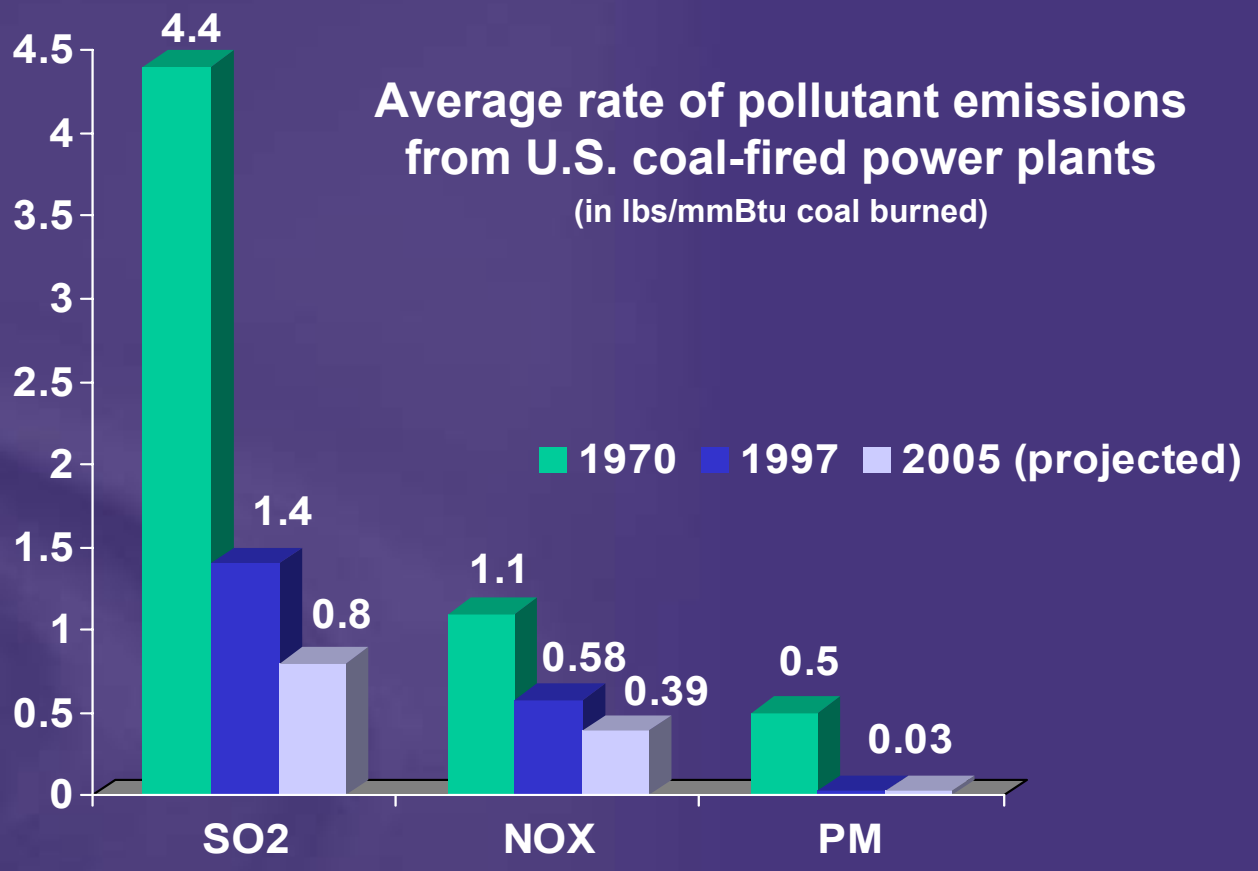
- NO_X Control Technologies
  - 75% of existing U.S. coal-fired units have been, or currently are being, retrofitted with low-NO_X burners
  - An estimated 30% of U.S. coal-fired generating capacity will incorporate SCR technology by 2004
  - Over 60 million tons of NO_X emissions have been avoided since 1970 based on average fleet emissions
- Fluidized Bed Combustion Technologies
  - FBCs offer inherently low NO_X emissions, high combustion and SO_2 capture efficiency, and extreme fuel flexibility
    - Six FBCs in Pennsylvania are using coal waste as fuel, eliminating an environmental problem, saving $1 billion in fuel costs, and avoiding 1.8 million tons of NO_X emissions over their life

Benefits Legacy from CCT Program and Associated R&D

- SO_2 Control Technologies
  - An estimated 30% of U.S. coal-fired generating capacity will incorporate FGD technology by 2002
  - 127 million tons of SO_2 emissions have been avoided since 1970 as a result of FGD installations



Environmental Benefits of CCT



The U.S. uses two-and-a-half times the coal it did in 1970, yet pollutant emissions have decreased

For the future – increased coal use will bring pressure to reduce emissions even further

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Power Plant Improvement Initiative

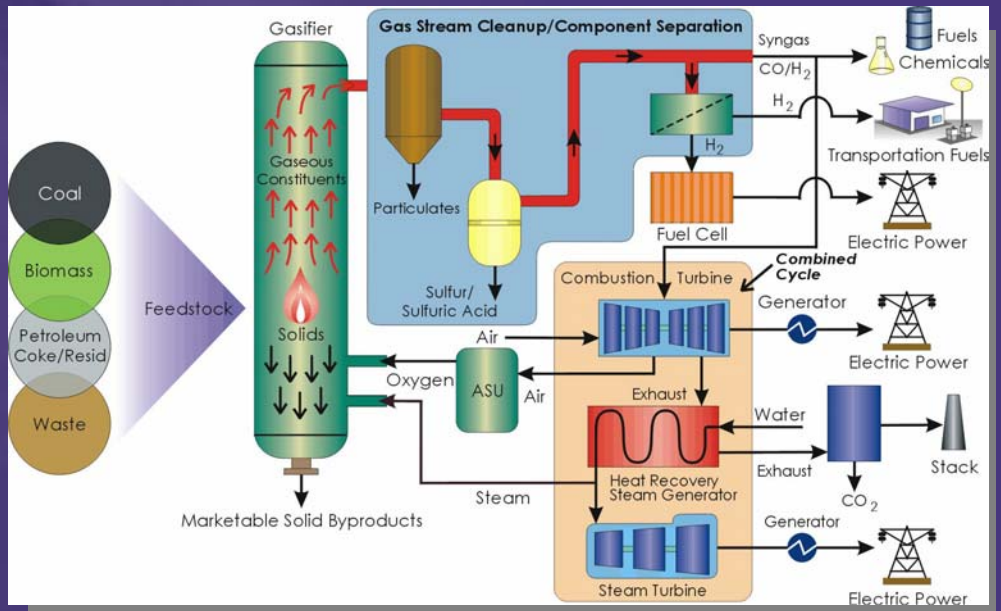
- Established in FY 2001 through transfer of $95 million from previously appropriated CCT Program funds
- Supported one solicitation incorporating CCT Program principles, including minimum 50% industry cost sharing
- Resulted in 24 proposals valued at $535 million
- Seven projects valued at $111 million, of which DOE is projected to fund approximately $51 million (46%), subject to negotiation
- Estimate completion of negotiation and cooperative agreement awards by Spring 2002
- Of 7 projects, 3 address NO_x control, 1 addresses multi-contaminant control (NO_x, SO_2, $PM_{2.5}$, mercury, and acid gases), 1 addresses $PM_{2.5}$ control, 1 addresses improved efficiency and reliability, and 1 addresses solid waste utilization

Clean Coal Power Initiative

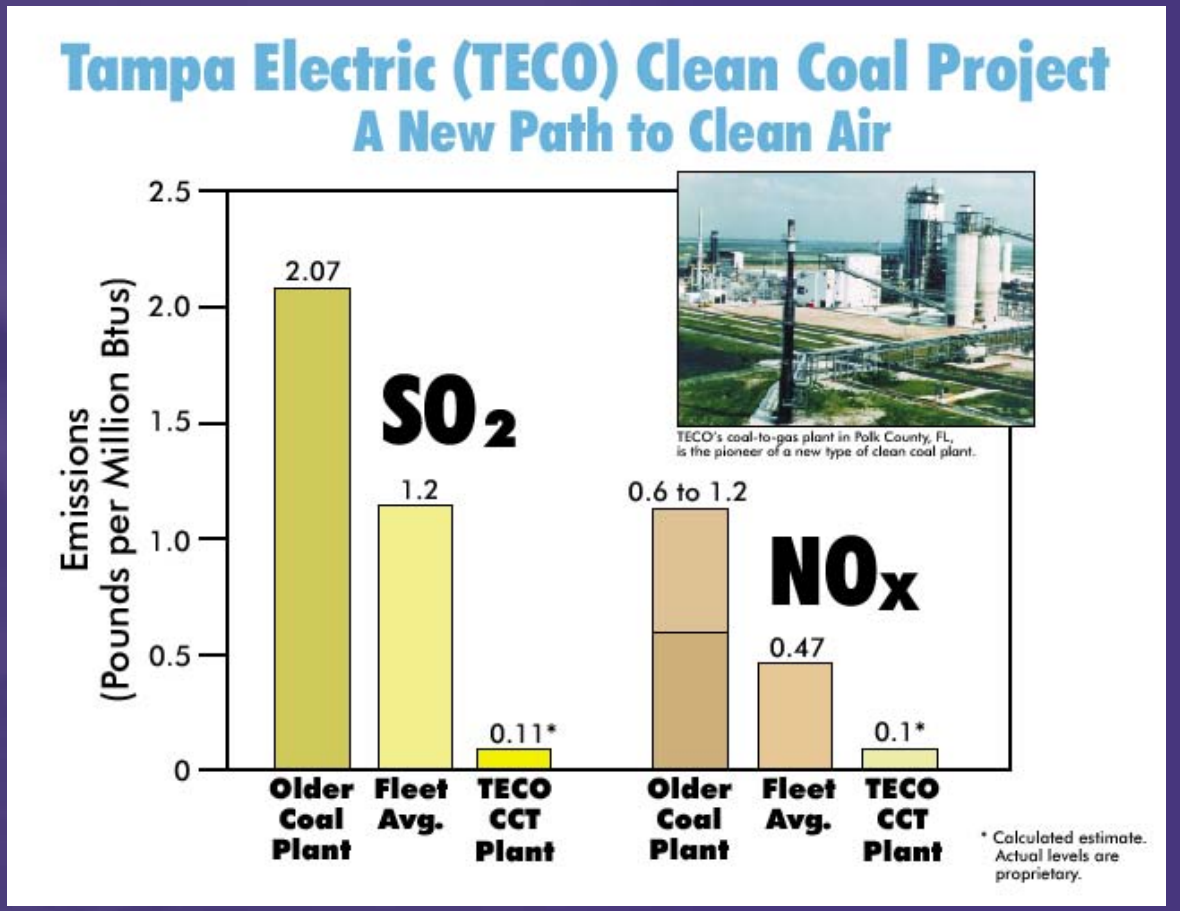
- Cooperative, cost-shared, $2 billion, ten year program between government and industry to:
  - Demonstrate emerging technologies in coal-based power generation
  - Accelerate emerging technologies deployment to commercial use
- Provides early demonstration opportunities for core coal and power RD&D as precursor to Vision 21
- Ultimate Goals: high efficiency with carbon management
  - Move away from existing plant upgrades (mercury, NO_X, particulates)
  - High efficiency, low CO_2
  - Sequestration ready

Gasification-based Systems

- Converts solid and liquid feedstocks to synthetic gas that can be easily cleaned of pollutants
- Converts potential pollutants to salable by-products such as sulfur, construction materials, and abrasives
- Enables production of electricity, steam, clean transportation fuels, chemicals, hydrogen, and natural gas substitute
- Enables CO_2 separation and capture



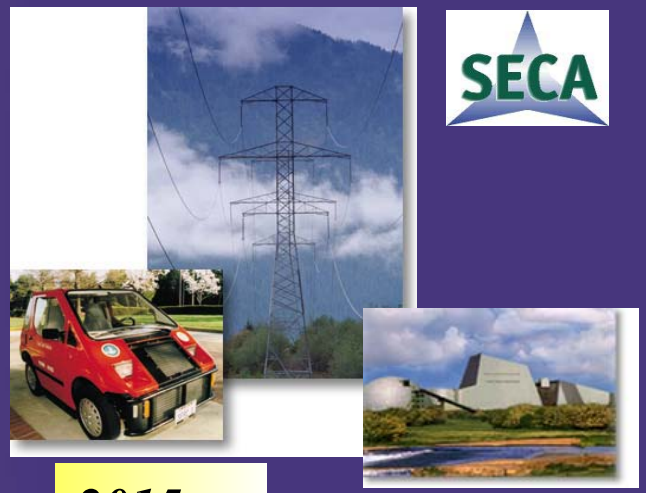
Demonstrated Success in Gasification-based Systems



Distributed Generation

- Fuel cells are being developed for distributed generation (DG) applications
- The Solid State Energy Conversion Alliance (SECA) is working specifically toward mass customization of 3-10kW fuel cell module
- Integration of fuel cell and turbine into a hybrid system will lower system cost and improve overall system efficiency

SECA Development: Progressive Applications



SECA

2003-2005

- Prototype testing
- **$800/kW**
- Auxiliary power
- Residential

2010

- **$400/kW** stationary units

2015

- 70-80% efficient plants
- $50/kW propulsion

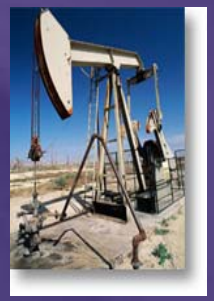
Ultimate Application: Vision 21 systems using syngas or H_2

Carbon Sequestration

Capture and Storage

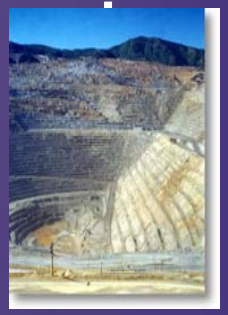
Unmineable Coal Seams

Deep Ocean Injection



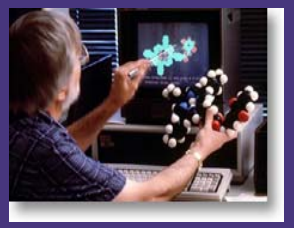
Depleted Oil / Gas Wells, Saline Reservoirs

Enhance Natural Processes



Mineral Carbonation

Forestation



Enhanced Photosynthesis

Iron or Nitrogen Fertilization of Ocean

Provide technology options that address CO_2 stabilization at a target cost of $10/ton of carbon removed

Carbon Sequestration
(cont'd)

- Near Term
  - Focus on reducing cost and showing feasibility of capture and separation of CO_2 from power plants, with sequestration in geological structures (enhanced oil recovery, coal bed methane – reduce net cost from $200/ton carbon to $30-$70 /ton carbon)
- Long Term
  - Greater emphasis on advanced reuse and conversion concepts with target costs of $10/ton carbon (0.2 cent/kwh impact on electricity costs)
- Longer Term
  - Integrate with Vision 21 power facility designs for use with both gasification and combustion systems

Sequestration: A Dynamic Program

- Diverse Research Portfolio: ~ 60 projects
- Strong Industry Support: ~ 40% cost share
- Example Accomplishments (FY 2002):
  - Complete an initial test to validate diagnostics and models for tracking injected CO_2 in a depleted oil reservoir (Sandia/Strata)
  - Begin full-scale project on sequestering CO_2 in unmineable coal seams (Consol)
  - Partner with federal, state, and local agencies in Kentucky to demonstrate terrestrial sequestration in mined lands (University of Kentucky)
  - Initiate full-scale monitoring and verification project on CO_2 injection into a depleting oil reservoir (Dakota/Weyburn)
  - Complete initial database on CO_2 storage potential of US geologic formations in 5 State Region (MIDCARB, State Geologic Consortia)

CO_2 Storage Capacities

Worldwide CO_2 Storage Potential

Storage Option	Capacity (billion tons)
Deep Ocean	5,100 – 100,000
Deep Aquifers	320 – 10,000
Depleted Oil Reservoirs	500 – 1,000
Depleted Gas Reservoirs	150 – 700
Coal Seams	150 – ???
Forests	4.4 per year
Carbonate Storage on Land	Infinite

Sources: IEA Greenhouse Gas R&D Programme; Advanced Resources International estimates for coal seams

Potential greatly exceeds current global emissions of 21 billion tons per year CO_2

Vision 21

- Virtually pollution free
  - Sulfur/nitrogen pollutants converted to chemicals, fertilizers, etc.
- Double power efficiencies
  - 60%+ (compared to 33% today), reduces CO_2 emissions by 40%
- Multiple products
  - Combined heat and power, plus liquid fuels/chemicals boosts overall efficiencies to 80%+

Today	2005	2010	2015
Adv. Pulverized & Fluidized Combustors	Ultra-Super Critical Steam Systems	Hybrid Gasifier/Combustor, Fuel Cell/Turbine Systems	
Gasification Combined Cycle	High Performance Heat Exchangers	Advanced Emission Controls	
Gas Turbines	Membrane/Other Gas Separation	Liquids/Heat Coproduction	
Emission Controls	Fuel Flexible Gasifiers and Gas Turbine/Fuel Cells	CO_2 Capture	
Fuel Preparation	Carbon Sequestration R&D	Carbon Sequestration	
Liquid Synthesis			

Vision 21 Cost Reduction Goals

	Present	2015 Goal
IGCC Capital Cost	$1200 / kW	$900 / kW*
Fuel Cell Capital Cost	$ 1500/kW**	$400 / kW
Hydrogen Production (from coal)	$6.83/mmBtu	$4.00/mmBtu
Oxygen Production	Cryogenic-air separation	Reduce capital cost 35% (membranes)
Liquid Fuels Production	$28/bbl-crude equivalent	$20/bbl-crude equivalent
Carbon Sequestration	$140 – $200 per ton carbon	$10 per ton carbon
Cost of Electricity	Fuel cost dependent	10% less for equivalent fuel cost

** Based on cost reductions in flexible turbines, gas separation and conditioning, and fuel cells)*

*** Market entry target cost*

Vision 21 Technology Targets

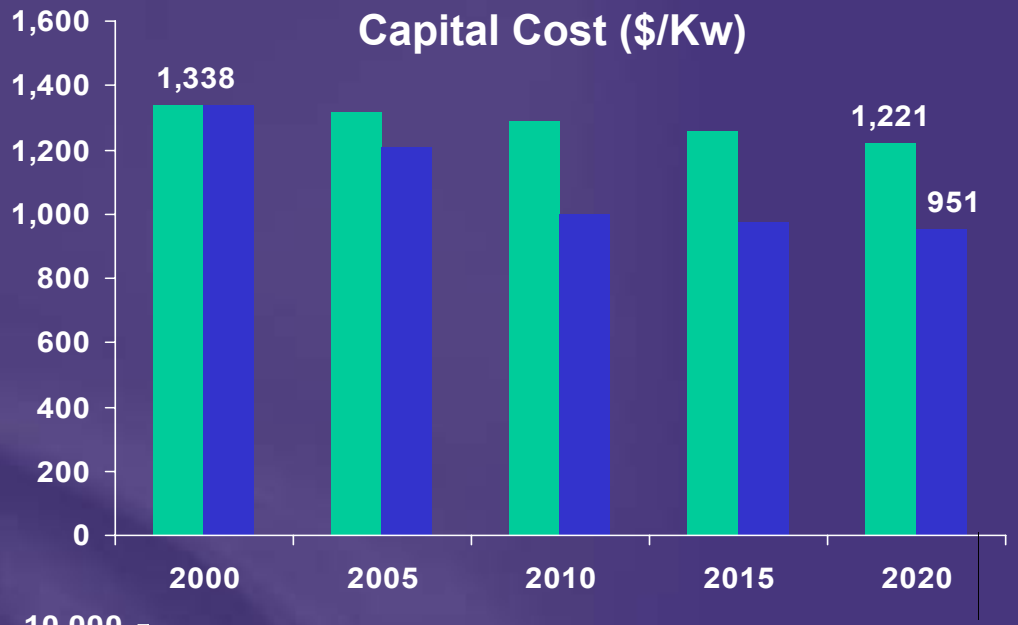
CCT Program → **R&D Program**

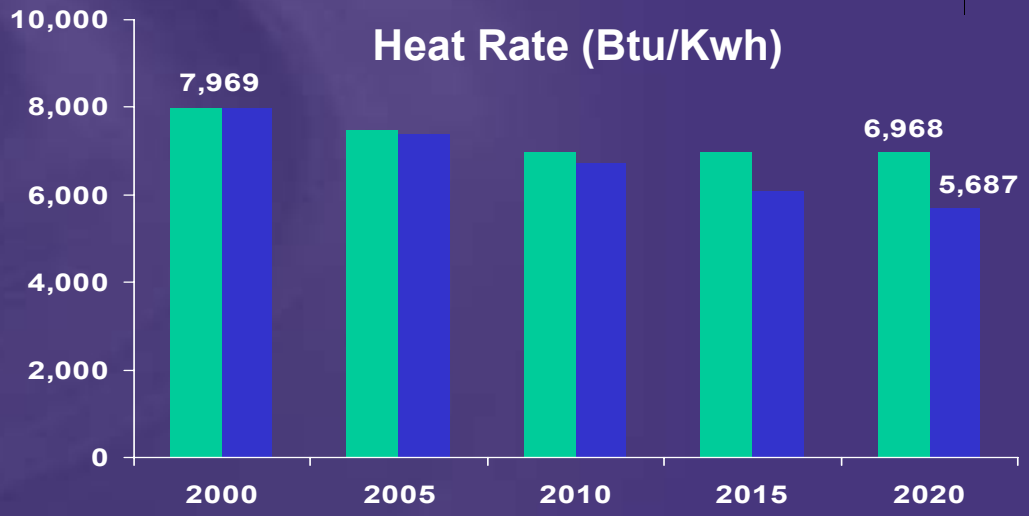
Foundation — **Stepping Stones to Vision 21**

	2000	2005	2010	2015-Vision 21
Efficiency	42%	47%	60%	>60%
Emissions	1/6 NSPS	1/10 NSPS	1/10 NSPS	Near-Zero
CO_2 Reduction	24%	32%	47%	No Net CO_2 w/ Sequestration
Cost of Energy	← 10-20% lower →			

Source: DOE Program Data

Coal IGCC Cost and Performance





Source: EIA Annual Energy Outlook 2002

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Critical Path to Success for Emission Reductions

- Short Term: Affordable environmental technologies for existing coal-fired power plants
  (mercury control, NO_X, SO_2 particulates)
- Mid Term: Much cleaner, more efficient options for new coal and gas plants, 2005 – 2015
  (IGCC, advanced combustion technologies)
- Long-Term: Near-zero emission, high efficiency coal and gas power plants – with low-cost carbon sequestration – by 2015
  (Vision 21 systems, fuel cells)

Strategy

- Foster complementary, integrated programs
  - R&D, demonstrations, deployment incentives
  - Build from a foundation of successes
- Leverage funds and accelerate technology transfer via government / industry partnerships
  - Focus on technology needs not met by private sector, and providing a substantial public good
- Continually re-assess market situation, external technology drivers, technology progress – and adjust RD&D program
  - Work with regulatory agencies to ensure regulations are science-based and exploit emerging technologies